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Antenne

Antenne

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EP-A- 0 593 185
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WO-A-92/16980
US-A- 4 442 438

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Description

[0001] The invention relates to an antenna structure for a radio transceiver.

[0002] Mobile phones operating in cellular networks are rapidly becoming the most important means of personal communications used to convey speech, telefax messages, and data in electronic form via communications networks from one user to another. Such a mobile phone is used in the following as an example of a radio set for which an antenna can be used.

[0003] Cellular telephone systems are used in different parts of the world, where operating frequency ranges deviate considerably from one another. Of digital cellular telephone systems, the operating frequencies of the GSM system (Groupe Speciale Mobile) are around 900 MHz, those of the JDC (Japanese Digital Cellular) in the ranges of 800 and 1500 MHz, those of the PCN (Personal Communication Network) in the range of 1800 MHz, and those of the PCS (Personal Communication System) in the range of 1900 MHz.

[0004] The mobile phones intended for these systems generally use simple cylindrical coil antennas, i.e., helical antennas, or rod antennas formed of straight conductors, due to their low manufacturing costs and relatively high electrical performance. The resonance frequency of the antenna is defined by its electric length, which has to form a certain part of the wavelength of the radio frequency in use. The electric length of a helical antenna used on mobile phone frequencies is preferably, e.g., $3\lambda/4$, $5\lambda/4$, or $\lambda/4$, in which λ is the wavelength being used. Correspondingly, the electric length of a rod antenna is preferably, e.g., $\lambda/2$, $5\lambda/8$, $3\lambda/8$, or $\lambda/4$. Solutions are also known in which the rod part and the helix part can be connected alternately to the antenna port of the radio set, as well as rod-helix serial connections which can be pushed partly inside the telephone (e.g., patent publication WO 92/16980). The aim of these solutions is generally to make the antenna as small as possible when in storage and transportation position, but such that it can be pulled out when necessary for a better connection.

[0005] Since the resonance frequency of the antenna according to prior art depends on the wavelength in the manner described above, one antenna can only be used in a mobile phone intended for the cellular telephone system of one frequency range. However, in some cases it is preferable that one and the same telephone can also be used in another frequency range. In these cases, a viable antenna solution is needed in addition to other appropriate RF-parts.

[0006] The easiest solution would be to provide the telephone with at least two separate replaceable antennas, of which the user could place in his telephone the one corresponding to the frequency range of the system he is using at that time. However, it is probable that the needed replacement antenna cannot be found at that time. Continuous replacing of antennas also strains the antenna plug and may cause contact disturbances in the course of time. Another alternative is to prepare at least two fixed, differently dimensioned antennas at different points of the telephone, of which, by using a switch, the user selects the one corresponding to the frequency range of the system being used. This increases the number of parts of the telephone and, consequently, the manufacturing costs.

[0007] U.S. patent No. 4 442 438 discloses an antenna structure which resonates on two frequencies and comprises essentially two helices HX1, HX2 and one rod element P1, according to Fig. 1. Helices HX1 and HX2 are installed sequentially in the direction of the symmetry axis of the structure and their adjacent ends A1 and A2 form the feed point of the composite structure. Rod element P1 is partly inside the upper helix HX1, extending slightly outside, and its feed point A3 is at the lower end thereof. RF signals are brought to this feed point A3 through coaxial conductor KX joining with the symmetry axis of the structure, the coaxial conductor going through the lower helix HX2. Feed point A3 of the rod element is connected to lower end A1 of the upper helix and the lower helix is connected, at the upper end A2 thereof, to the conducting and grounded sheath of coaxial conductor KX. The first resonance frequency of the structure is the resonance frequency of the combined structure formed by helices HX1 and HX2; 827 MHz in the exemplifying embodiment. The second resonance frequency of the structure is the common resonance frequency of the upper helix HX1 and rod element P1, which is 850 MHz in the exemplifying embodiment. Helix HX1 and rod element P1 are thus dimensioned so that they comprise essentially the same resonance frequencies.

[0008] The structure disclosed in the U.S. patent is relatively complex and its physical length in the direction of the symmetry axis is the sum of the physical lengths of lower helix HX2 and rod element P1. The most troublesome point of the structure from the point of view of the manufacturing technique is the feed point arrangement in the middle of the antenna, in which lower end A3 of the rod element and lower end A1 of the upper helix have to be galvanically connected, and the lower helix has to be connected at its upper end A2 to the sheath of the coaxial conductor feeding the rod element. The difference between the two resonances obtained by using the structure is small according to the material disclosed in the patent because upper helix HX1 and rod element P1 have to be dimensioned so that they have essentially the same common resonance frequencies, therefore, it cannot be implemented in telephones operating on the GSM and PCN frequencies, for example. The descriptive part of the patent thus suggests, for the object of the invention, that the resonance frequency range of the mobile phone antenna should be widened so that it would better cover the whole frequency band in one cellular telephone system. It would be difficult to apply the structure to more than two resonance frequen-

cies.

[0009] In a European patent application published as EP-A-650 215 the antenna construction is built around a retractable whip antenna with a coaxial impedance matching element at its base. One embodiment of the structure comprises a coil antenna element at the top end of the coaxial impedance matching element so that there is a capacitor arranged to couple the whip antenna to the coil antenna element.

[0010] A previous European patent application of the applicant himself, published as EP-A-593 185, discloses the use of two coaxially placed helix antennas to widen the single useful frequency band of an antenna arrangement. The description refers to the restrictively narrow frequency band of a single helix when compared e.g. to the duplex separation of certain digital cellular systems. Various variations are shown about the general double helix theme.

[0011] The characteristic features of an antenna according to the invention are recited in the characterising portion of claim 1. According to an aspect of the invention described therein there may be provided an antenna structure comprising at least two discrete resonating elements. A first element, preferably a straight conductor, i.e., a rod element, can be placed partly or fully inside a second element, preferably a cylindrical coil conductor, i.e., a helical element. By adding a third antenna around the structure, preferably a cylindrical coil conductor, whose inner diameter is larger than the outer diameter of the first antenna element, a third resonance frequency may be obtained. Feeding of the resonating antenna elements may be effected from a common feed point, or all the elements may comprise their own feed points.

[0012] Exemplary embodiments, in accordance with the present invention, may provide an antenna suitable for radio communications, especially for mobile phones, and may comprise at least two discrete resonance frequency ranges. Also the embodiments may provide an antenna structure whose resonance frequencies can be freely selected when designing the antenna. Further more the embodiments may provide a mobile phone antenna with at least two frequencies whose structure may be simple and reliable and which may be well-adapted to mass production. Further embodiments may be of a small-size and may be at least dual-frequency.

[0013] The antenna structure in accordance with the invention may comprise a first antenna element and a second antenna element, which is a cylindrical coil conductor, and may be characterized in that

- the said first antenna element comprises a part which is inside the said cylindrical coil conductor, and
- the resonance frequency of the said first antenna element is different than the resonance frequency of the said second antenna element.

[0014] In the course of the development work resulting in the creation of embodiments in accordance with the invention it was observed that a rod antenna can be placed inside a helical antenna without the antennas disturbing each other's operation considerably, when they are dimensioned on different resonance frequencies. The resonance frequency of the helical antenna, which is a part of the combined structure, may be slightly lower than the resonance frequency of a discrete helical antenna of corresponding dimensions. Correspondingly, the resonance frequency of the rod antenna, which is a part of the combined structure, may be slightly lower than that of a discrete rod antenna of corresponding dimensions. By dimensioning the parts of the antenna structure in the manner described below, the resonance frequencies may be adapted so that the combined structure has its first resonance frequency range preferably in the operating frequency range of some cellular mobile phone system, a second resonance frequency range preferably in the operating frequency range of another cellular mobile phone system, and possibly, a third resonance frequency in the operating frequency range of a third cellular mobile phone system.

[0015] Embodiments of the invention will now be described, by way of example, with with reference to the appended figures in which:

Fig. 1 presents schematically a known antenna structure with two resonance frequencies,

Fig. 2 presents schematically an antenna structure in accordance with the invention,

Fig. 3 presents graphically the behaviour of a calculated S-parameter S_{11} of the antenna according to the embodiment of Fig. 2 as the function of frequency,

Fig. 4 presents schematically another antenna structure in accordance with the invention,

Fig. 5 is a cross-section of an embodiment of the antenna structure in accordance with the invention,

Fig. 6 presents schematically a third antenna structure in accordance with the invention.

[0016] Reference has been made above to Fig. 1 in connection with the description of prior art.

[0017] Fig. 2 presents an antenna structure comprising helical element HX3 and rod element P2 which are manufactured of conducting material and connected at their lower ends, with respect to the operating position presented in the figure, to common feed point A4. The electrical length of helical element HX3 corresponds to a fraction of the wavelength of an operating frequency of the structure in a manner known per se, and its physical length in the direction of the symmetry axis, i.e., the longitudinal axis of the structure mainly depends on how closely it is wound, i.e., what the pitch of the helix is. The electrical length of rod element P2, which is essentially the same as its physical length, corresponds, in a manner known per se, a fraction of the wavelength of another

operating frequency of the structure, and is preferably higher than the length of helical element HX3 in the direction of the symmetry axis, whereby it extends partly outside helical element HX3 at the upper end thereof with respect to the operating position. This is not necessary as such because calculations have proven that a rod element which is fully inside a helical element functions satisfactorily as an antenna; an embodiment is otherwise similar to the one in Fig. 2, except rod element P2 only comprises part P2a inside the helix. Ground plane GND made of conducting material envelopes feed point A4.

[0018] The operation of the antenna structure was analyzed by simulation software, therefore, a computer model was made of it. In the model, the rod element P2 is a straight conductor and helical element HX3 consists of interconnected, sequential straight conductor parts, 16 per each turn of the helix. S-parameter S_{11} calculated in one simulation of an antenna in accordance with the invention, depicting the RF power reflected from the antenna port back to the circuit feeding it, is presented graphically in Fig. 3 as a function of frequency. According to the dimensioning examples used in this simulation, the resonance frequency of rod element P2 functioning as a part of the antenna structure is 1.9 GHz, and its input impedance is slightly less than 50 Ω. The voltage standing-wave ratio (VSWR) counted for it is better than 2:1 and reflection losses are less than -10dB on a frequency band whose width is 16% of the nominal frequency.

[0019] Correspondingly, according to calculations made with the same measurement values, helical element HX3 comprises, as part of the combined antenna structure, a resonance frequency of 910 MHz. Its input impedance is fairly low, so a ratio of 8:1 is obtained in calculations as the voltage standing-wave ratio. A bandwidth of half the power, i.e., 3dB, is about 13%. The reflection losses of helical element HX3 are considerably higher than those of rod element P2 but losses can be reduced when necessary and the input impedance increased by using matching circuits which comprise RF-technique known by those skilled in the art.

[0020] Calculatory analyses have also been used to study the effect of antenna elements HX3, P2 on each other's radiation patterns. Calculations indicate that radiation patterns do not change considerably with respect to the radiation patterns of discrete antennas. The presence of rod element P2 perhaps slightly decreases the radiation pattern of helical element HX3 in the opposite direction to feed point A4, but not considerably. No significant alteration can be perceived in the radiation pattern of rod element P2.

[0021] Fig. 4 presents another embodiment of the antenna structure in accordance with the invention in which both helical element HX4 and rod element P3 have their respective feed points. Feed point A5 of the rod element is preferably placed on the symmetry axis of the structure because then rod element P3 does not have to be bent. Feed point A6 of the helical element is preferably placed so that the helix wire is bent, with respect to the operating position presented in the figure, from the periphery of the lowest turn directly towards ground plane GND, and feed point A6 is formed at the point where the helix wire meets the ground plane. In this embodiment it is especially easy to build a separate optimized matching circuit for both antenna elements.

[0022] If an antenna comprising three resonance frequency ranges or bands is to be manufactured to be used in mobile phones of, e.g., the GSM frequency range (900 MHz), the higher JDC frequency range (1500 MHz), or the PCS frequency range (1900 MHz), a third antenna element can be added to the above-described antenna structures in accordance with the invention, which is preferably a cylindrical coil conductor, i.e., helix HX5. Its inner diameter is preferably wider than the outer diameter of the first helical element HX4, whereby it fits around the smaller helical element according to Fig. 6. In the antenna with three antenna elements the feed points can be the same, or each antenna element P3, HX4, HX5 can comprise a respective feed point A5, A6, A7, as shown in Fig. 6. The diameter of the third antenna element can also be of the same size as the first helical element, whereby the helical elements are placed sequentially in the direction of the longitudinal axis of the structure, or they are interwound.

[0023] The conducting parts of an antenna structure in accordance with the invention, i.e., rod element P2; P3, and helical element HX3; HX4; HX5 can preferably be manufactured of stainless steel wire, phosphorus bronze wire, beryllium copper wire, or some other known conducting material. The rod element may be cut from a straight wire to a suitable length, and if it comprises part P2b which is outside helical element HX3; HX4; HX5, this part can be bent to save space. The helical element(s) may be preferably manufactured by winding. In order to improve the conductive properties, the rod or helical elements or both of them can be plated with gold, silver, or some other material which conducts particularly well. When the antenna in accordance with the invention is placed in the mobile phone, the ground plane which is marked with reference GND in the figures, may be the ground plane of the telephone.

[0024] The usability of the antenna structure in accordance with the invention as a mobile phone antenna can be improved by coating it with protective dielectric coating S1 according to Fig. 5, in the same way as mobile phone antennas of prior art are coated, excluding feed point A4 and possibly connecting part L1 which connects the antenna structure to body RD of the radio set. Protective coating S1 is preferably of some known elastic material which is well-adapted to the mass production of antennas, such as injection-moulded plastic or a rubber mixture.

[0025] If rod element P2, P3 is longer than helical element HX3, HX4, HX5 in the direction of the longitudinal axis of the antenna structure, it can be provided with a

telescopic structure in a similar way as in solutions according to prior art. This provides the advantage that in areas where data communication systems based on the resonance frequency of helical element HX3, HX4, HX5 are the only systems used, the outer dimensions of radio sets using antennas according to the invention can be made smaller. In this case the rod element does not disturb the operation of the helical element as an antenna even to the extent where the rod element is inside the helical element. The entire antenna structure can also be provided with a sliding mechanism through which it can be partly pushed inside and pulled out of the shell of the mobile phone to save space when needed.

[0026] An antenna structure according to the invention can be applied to radio communications where two different frequency ranges are used, preferably on radio frequencies such as UHF and VHF. The resonance frequencies only depend on the dimensions of the different parts of the antenna, so they can be selected relatively freely during the designing and manufacturing stages. Since the antenna structure comprises, in a preferred embodiment, only two parts and a possible connecting part for attaching it to the radio set, and a possible protective cover, its structure is very simple and it is very well-adapted to mass production. Placing the antenna elements inside one another makes the structure small compared to, e.g., the structure presented in U.S. patent No. 4 442 438 and handled above in connection with prior art, whereby it is very well suited to modem, small mobile phones.

Claims

1. An antenna for a radio transceiver, comprising a first resonating antenna element (P2; P3) and a second resonating antenna element (HX3; HX4) which is a coil conductor, of which antenna elements said first antenna element (P2; P3) comprises a part (P2a) which is inside the coil conductor (HX3),
characterized in that

   - the resonance frequency of said first antenna element (P2; P3) is in an operating frequency range of a cellular mobile phone system and of the order of 1.9 GHz, and the resonance frequency of said second antenna element (HX3; HX4) is in an operating frequency range of a cellular mobile phone system and of the order of 900 MHz.

2. An antenna according to Claim 1, **characterized in that** said first antenna element (P2; P3) is a straight conductor.

3. An antenna according to Claim 1 or 2, **characterized in that** said second antenna element (HX3; HX4) is a cylindrical coil conductor.

4. An antenna according to Claims 1, 2 or 3, **characterized in that** the feed point (A4) of said first antenna element is the same as the feed point (A4) of said second antenna element.

5. An antenna according to Claim 3, **characterized in that** the feed point (A5) of said first antenna element is on its longitudinal axis, and the feed point (A6) of said second antenna element is on its cylindrical envelope.

6. An antenna according to any of the preceding Claims, **characterized in that** it further comprises a third antenna element (HX5) which is a coil conductor disposed around the first (P2; P3) and second (HX3; HX4) antenna elements and whose resonance frequency is in an operating frequency range of a cellular mobile phone system and of the order of 1500 MHz.

7. An antenna according to Claim 6, **characterized in that** said third antenna element (HX5) is a cylindrical coil conductor.

8. An antenna according to any of the preceding Claims, **characterized in that** the antenna comprises a connecting part (L1) for connecting it mechanically and electrically to the radio transceiver.

9. An antenna according to any of the preceding Claims, **characterized in that** it comprises a protective cover (S1) of a dielectric material for protecting the antenna elements (P2; P3; HX3; HX4; HX5).

10. An antenna according to any of the preceding Claims, **characterized in that** at least one antenna element (P2; P3; HX3; HX4; HX5) is retractable within said radio transceiver.

Patentansprüche

1. Antenne für einen Funk-Sender-Empfänger, mit einem ersten in Resonanz schwingenden Antennenelement (P2; P3) und einem zweiten in Resonanz schwingenden Antennenelement (HX3; HX4), das ein Spulenleiter ist, wobei von diesen Antennenelementen das erste Antennenelement (P2; P3) einen Abschnitt (P2a) umfasst, der sich in dem Spulenleiter (HX3; HX4) befindet,
dadurch gekennzeichnet, dass
die Resonanzfrequenz des ersten Antennenelements (P2; P3) in einem Betriebsfrequenzbereich eines Zellenmobiltelephonsystems und in der Größenordnung von 1.9 GHz liegt und die Resonanzfrequenz des zweiten Antennenelements (HX3; HX4) in einem Betriebsfrequenzbereich eines Zellenmobiltelephonsystems und in der Grö-

ßenordnung von 900 MHz liegt.

2. Antenne nach Anspruch 1, **dadurch gekennzeichnet, dass** das erste Antennenelement (P2; P3) ein geradliniger Leiter ist.

3. Antenne nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** das zweite Antennenelement (HX3; HX4) ein Zylinderspulenleiter ist.

4. Antenne nach den Ansprüchen 1, 2 oder 3, **dadurch gekennzeichnet, dass** der Speisepunkt (A4) des ersten Antennenelements der gleiche ist wie der Speisepunkt (A6) des zweiten Antennenelements.

5. Antenne nach Anspruch 3, **dadurch gekennzeichnet, dass** der Speisepunkt (A4) des ersten Antennenelements auf seiner Längsachse liegt und der Speisepunkt (A6) des zweiten Antennenelements auf seiner zylindrischen Umhüllungsfläche liegt.

6. Antenne nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** sie ferner ein drittes Antennenelement (HX5) umfasst, das ein Spulenleiter ist, der um das erste (P2; P3) und das zweite (HX3; HX4) Antennenelement angeordnet ist und dessen Resonanzfrequenz in einem Betriebsfrequenzbereich eines Zellenmobiltelephonsystems und in der Größenordnung von 1500 MHz liegt.

7. Antenne nach Anspruch 6, **dadurch gekennzeichnet, dass** das dritte Antennenelement (HX5) ein Zylinderspulenleiter ist.

8. Antenne nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die Antenne einen Verbindungsabschnitt (L1) umfasst, der sie mechanisch und elektrisch mit dem Funk-Sender-Empfänger verbindet.

9. Antenne nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** sie eine Schutzabdeckung (S1) aus einem dielektrischen Material zum Schützen der Antennenelemente (P2; P3; HX3; HX4; HX5) umfasst.

10. Antenne nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** wenigstens ein Antennenelement (P2; P3; HX3; HX4; HX5) in den Funk-Sender-Empfänger einschiebbar ist.

Revendications

1. Antenne pour un émetteur/récepteur radio, comprenant un premier élément d'antenne résonnant (P2 ; P3) et un second élément d'antenne résonnant (HX3 ; HX4) qui est un conducteur en spirale, desquels éléments d'antenne ledit premier élément d'antenne (P2 ; P3) comprend une partie (P2a) qui est à l'intérieur du conducteur en spirale (HX3),
caractérisée en ce que
- la fréquence de résonance dudit première élément d'antenne (P2 ;P3) est dans une plage de fréquences de fonctionnement d'un système de téléphone mobile cellulaire et de l'ordre de 1,9 GHz, et la fréquence de résonance dudit second élément d'antenne (HX3 ; HX4) est dans une plage de fréquences de fonctionnement d'un système de téléphone mobile cellulaire et de l'ordre de 900 MHz.

2. Antenne selon la revendication 1, **caractérisée en ce que** ledit premier élément d'antenne (P2 ; P3) est un conducteur rectiligne.

3. Antenne selon la revendication 1 ou 2, **caractérisée ce** que ledit second élément d'antenne (HX3 ; HX4) est un conducteur en spirale cylindrique.

4. Antenne selon la revendication 1, 2 ou 3, **caractérisée en ce que** le point d'alimentation (A4) dudit premier élément d'antenne est le même que le point d'alimentation (A4) que celui dudit second élément d'antenne.

5. Antenne selon la revendication 3, **caractérisée** ce que le point d'alimentation (A5) dudit premier élément d'antenne est sur son axe longitudinal, et le point d'alimentation (A6) dudit second élément d'antenne est sur son enveloppe cylindrique.

6. Antenne selon l'une quelconque des revendications précédentes, **caractérisée en ce qu'**elle comprend, de plus, un troisième élément d'antenne (HX5) qui est un conducteur en spirale disposé autour des premier (P2 ; P3) et second (HX3 ; HX4) éléments d'antenne et dont la fréquence de résonance est dans une plage de fréquences de fonctionnement d'un système de téléphone mobile cellulaire de l'ordre de 1500 MHz.

7. Antenne selon la revendication 6, **caractérisée** ce que ledit troisième élément d'antenne (HX5) est un conducteur en spirale cylindrique.

8. Antenne selon l'une quelconque des revendications précédentes, **caractérisée en ce que** l'antenne comprend une partie de connexion (L1) pour la connecter mécaniquement et électriquement à l'émetteur/récepteur radio.

9. Antenne selon l'une quelconque des revendications précédentes, **caractérisée** ce qu'elle comprend un couvercle protecteur (S1) constituée d'un matériau

diélectrique pour protéger les éléments d'antenne (P2 ; P3 ; HX3 ; HX4 ; HX5).

10. Antenne selon l'une quelconque des revendications précédentes, **caractérisé en ce qu'**au moins un élément d'antenne (P2 ; P3 ; HX3 ; HX4 ; HX5) est rétractable à l'intérieur dudit émetteur/récepteur radio.

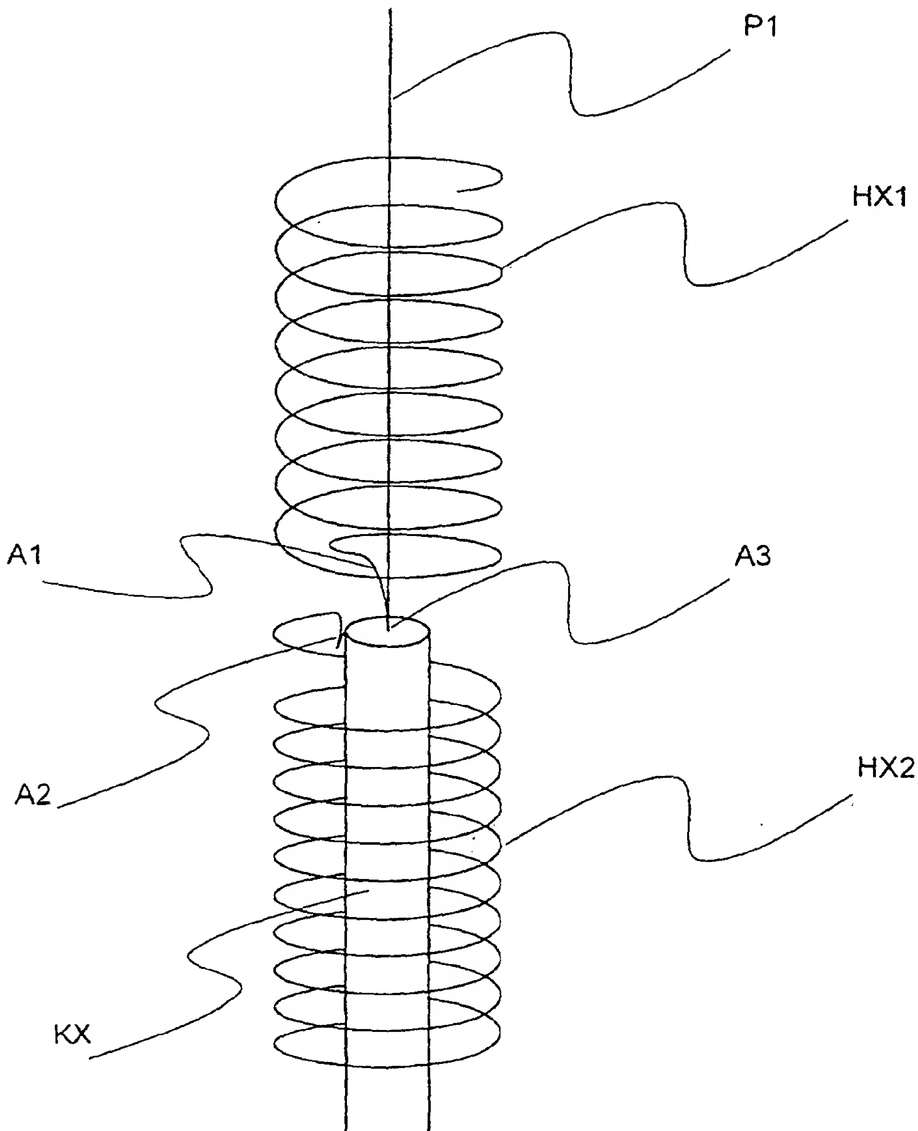

Fig. 1

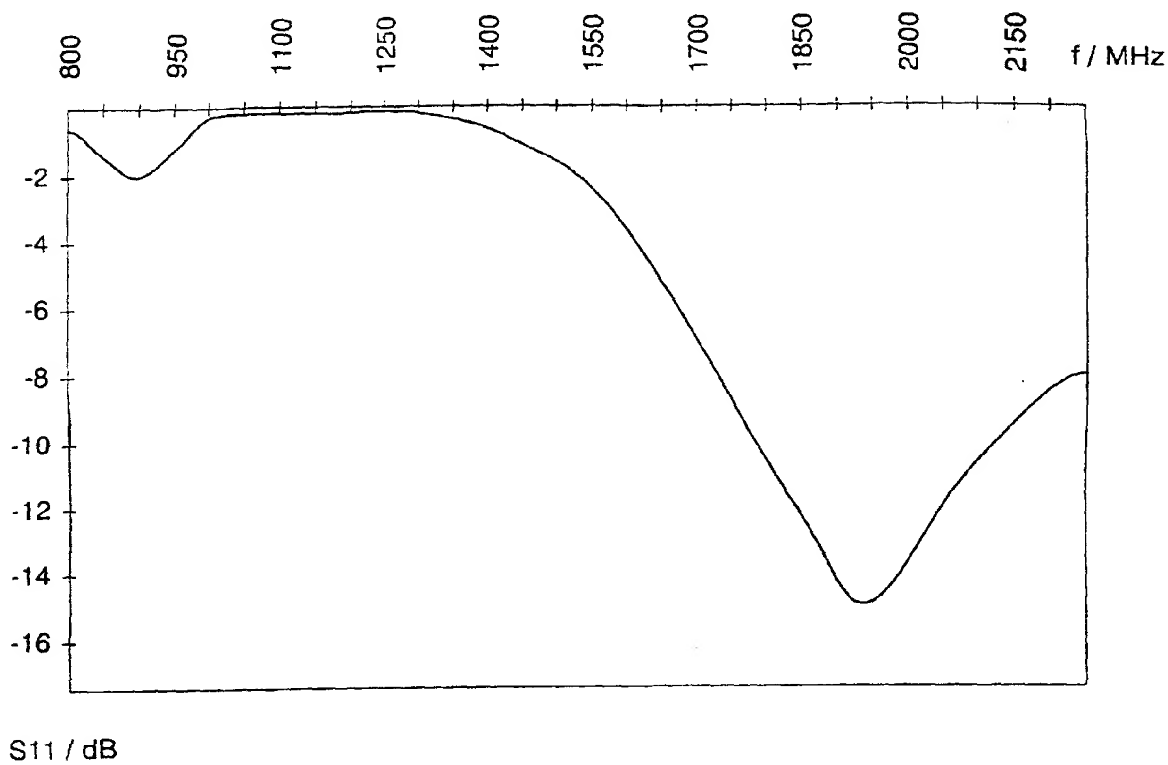
800
950
1100
1250
1400
1550
1700
1850
2000
2150
f / MHz
-2
-4
-6
-8
-10
-12
-14
-16
S11 / dB

Fig. 3

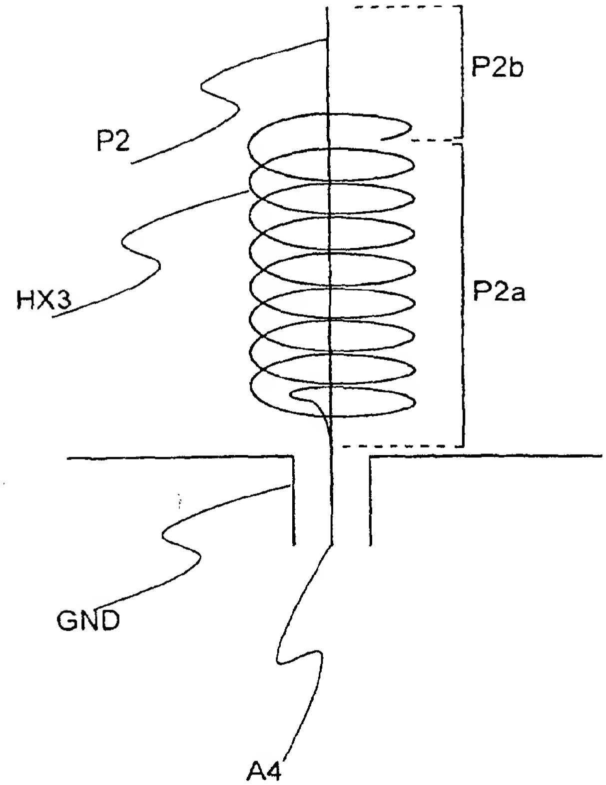

Fig. 2

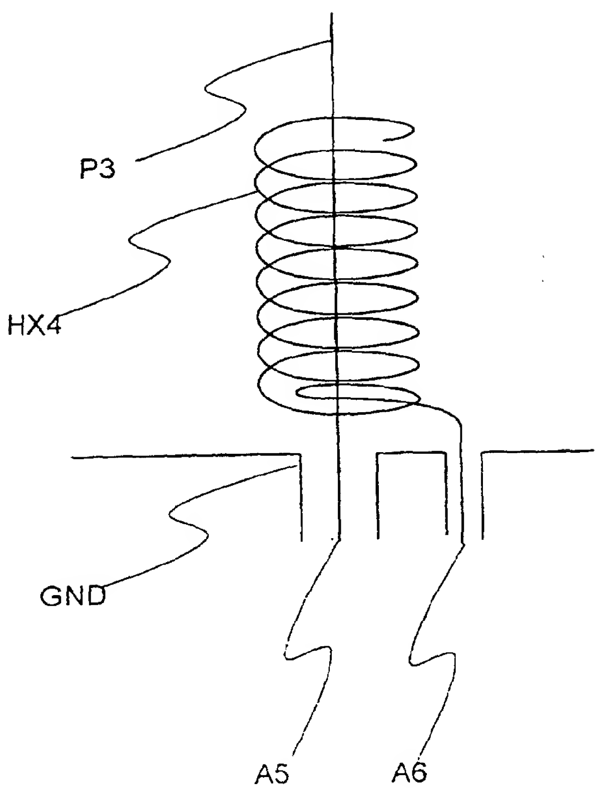

Fig. 4

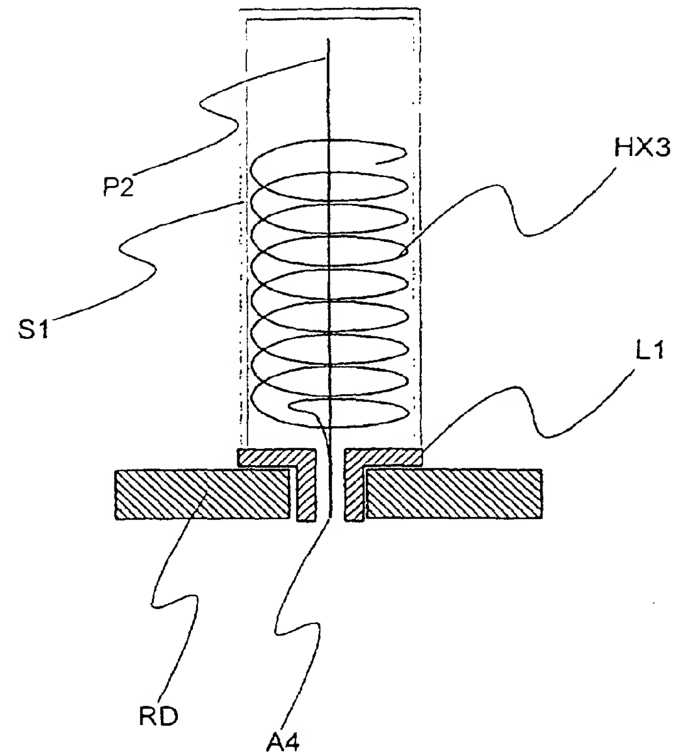

Fig. 5

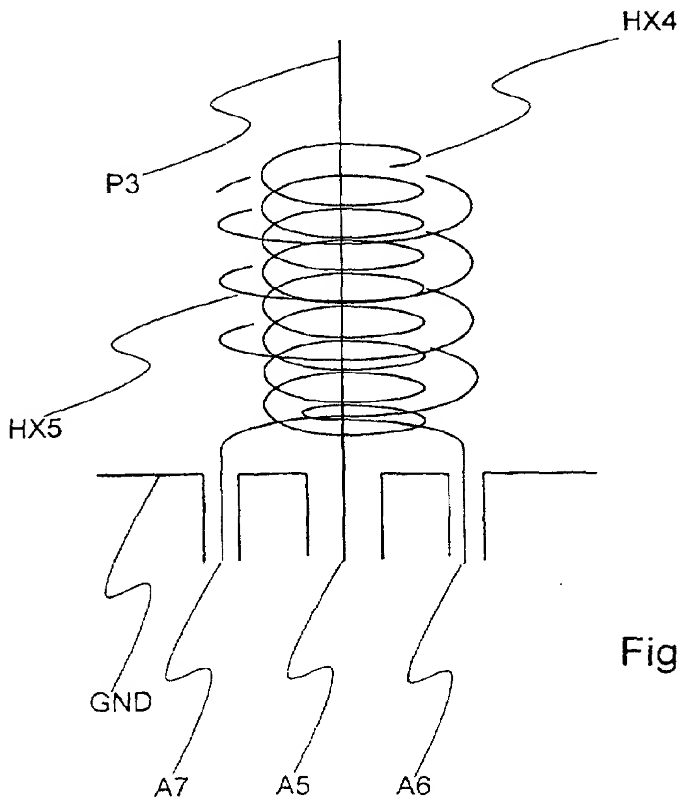

Fig. 6